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Eating behaviors in sailors of the United States Navy: Meal-to-sleep intervals

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Abstract

Background: Due to their long workdays and erratic watch schedules, sailors on United States Navy (USN) ships often eat meals close to their bedtime, which may contribute to sleep disruption. **Aim:** To assess the duration of meal-to-sleep (M-S) intervals in relation to timing of sailor workdays and watch schedules. **Methods:** Longitudinal field assessment of USN sailors performing their underway duties ($N = 234$). Participants completed questionnaires, wore actigraphs, and completed activity logs. **Results:** Approximately 35% of M-S intervals were <3 h in duration. M-S interval duration was associated with watchstanding status ($p < 0.001$) and the number of sections in the watchstanding schedule ($p < 0.001$). Sailors on the two-section watch schedule had, on average, the shortest M-S intervals (55 min) compared to sailors on three- or four-section watchbills (~4 h) and to non-watchstanders (4.85 h). **Conclusion:** Sailors on two-section watchbills often eat quite close to bedtime. To provide appropriate recommendations regarding healthy dietary patterns, we will continue assessing dietary behaviors and food choices of sailors while underway, especially as they relate to sailor work hours, circadian rhythms, and sleep practices.

Keywords

Meal-to-sleep intervals, dietary patterns of sailors, naval operational environment, circadian rhythms

Introduction

Nutrition is an important element of health, cognitive and physical performance, and recovery from injuries (Lieberman, 2003; Montain and Young, 2003; Tipton, 2010). Nutrition and dietary habits are known to affect sleep (Afaghi et al., 2007; Peuhkuri et al., 2012) but sleep also affects dietary patterns and metabolism (Res et al., 2012). Specifically, sleep restriction affects brain regions that regulate food intake by increasing the desire for high-calorie foods (Killgore et al., 2013). Combined with the reduced dietary restraint also caused by sleep deprivation, weight gain is a common occurrence when food is easily accessible (Markwald et al., 2013).

Timing of food consumption is also important for weight and metabolism, with regular nighttime eating potentially contributing to metabolic dysfunction (Allison and Goel, 2018). Studies in mice and humans have shown that consuming food during the circadian evening/night, compared with eating during the biological daytime, is associated with greater weight gain, higher percentage of body fat and body mass index, and a slower rate of weight loss (McHill et al., 2017; Garaulet et al., 2013). Sleeping soon after eating has also been associated with digestion issues (indigestion – dyspepsia), gastro-esophageal reflux, and gastro-esophageal reflux disease (GERD) (Fujiwara et al., 2005; Kinsey and Ormsbee, 2015). These disorders, in turn, have been associated with sleep disturbances, e.g., difficulty falling asleep, shorter sleep duration, poor sleep quality, sleep arousals, and early awakenings (Fujiwara et al., 2012). Hence, current guidance suggests that large meals should be avoided 3 h before sleep (Fuchs et al., 2014).

The United States Navy (USN) has regulations in place regarding the nutritional composition of meals. However, there are no such directives currently in place to protect sailors from poor dietary patterns of behaviors that may result from their work schedule. The importance of this issue becomes clear if we consider the bidirectional relationship between sleep and diet, and the fact that sleep deprivation and circadian misalignment are endemic in the naval operational environment (Shattuck et al., 2019).

Given this background, the Crew Endurance Team at the Naval Postgraduate School, Monterey, CA, has initiated a

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multi-year project to document the eating patterns of active duty service members (sailors) performing their normal duties while underway on ships of the USN. The first step, presented herein, is to assess the length of time between meals and bedtime as it relates to sailor occupational group and watchstanding status. Our hypothesis was that watchstanders and sailors standing watch on two-section watchstanding schedules eat closer to their bedtime than other sailors.

Methods

Participants

Sailors ($N = 234$) assigned to four surface ships of the USN were used in this study. All sailors in the ship's company were eligible to participate in the study and were deemed as "fit for duty", i.e., in good health. Study procedures were approved by the Institutional Review Board of the Naval Postgraduate School. Participants provided written informed consent.

Meal times

USN surface ships provide onboard personnel three main meals per day (breakfast: ∼0600–0700; lunch: ∼1100–1230; dinner: ∼1600–1800) and a fourth meal for night watchstanders around midnight (midnight rations – "midrats": ∼2330–0030). Depending on the ship and the watchbills that are being used, meal times may vary slightly outside these ranges.

Equipment and instruments

Participants' sleep was assessed by one of two brands of wrist-worn actigraphs (Motionlogger Watch, Ambulatory Monitoring, Inc. (AMI), Ardsley, New York; and Spectrum, Philips-Respironics (PR), Bend, Oregon) assisted by activity logbooks (Ancoli-Israel et al., 2015). Data for both devices were collected in 1-min epochs. Actigraphic analysis was performed with default parameters (AMI: Action-W ver.2.7.2155; PR: Actiware ver.6.0.0). Information from activity logs was used to manually determine start and end times of rest intervals using the actigraphy data as the primary source for the sleep analysis. Within each rest interval, the actigraphically assessed sleep was automatically calculated.

Participants completed two questionnaires. The pre-study questionnaire included demographic items (e.g., age, sex, rank, department). The post-study questionnaire asked participants which watchstanding schedule they used during the data collection period.

Study design and procedures

The information presented is a retrospective analysis of a subset of measures from multiple field assessments on USN ships between 2017 and 2018. The original data were collected using a prospective naturalistic design with an underway data collection period ranging from 7 to 18 days. Sailors were recruited using group presentations in the ships' mess decks (cafeteria). The goals of the recruitment were to achieve a study sample which would include at least 40% of the crew onboard, and be representative in terms of sex, ranks, and departments. In all cases, both sample size and representativeness were achieved.

Initially, volunteers completed the pre-study questionnaire and received their actiwatches and logbooks to document their daily routine in 15-min intervals. Even though sailors logged various activities in their logs, our focus in this study is "messing", i.e., the time spent eating a meal. Upon completion of the study, the participants filled out the post-study questionnaire.

Analytical approach

From the initial 536 sailors with activity log data, 234 were used for further analysis (302 sailors were excluded due to missing or incomplete activity log data). The two groups (sailors included in the analysis, sailors excluded) did not differ in terms of age (Wilcoxon Rank Sum test, $Z = 0.734$, $p = 0.463$), sex (Fisher's exact test, $p = 0.276$), rank (Fisher's exact test, $p = 0.228$), and department (Fisher's exact test, $p = 0.120$). Therefore, even after excluding 302 sailors, the 234 sailors used in analysis remained representative in terms of demographic and occupational characteristics.

Participants provided 1960 days of activity data (a median of 7 days per sailor). Even though these data had some missing 15-min intervals, imputation was not applied because (a) the pattern of missing data was not systematic, and (b) none of the missing 15-min intervals were during meal times.

First, we calculated the duration of the meal-to-sleep (M-S) intervals, i.e., the period of time between the end of the latest meal of the day to the beginning of the next sleep episode. Sailors were classified into two occupational groups. The "watchstander" group included sailors who stood watch, i.e., a period of time during which a sailor is assigned specific, detailed responsibilities on a recurring basis (Department of the Navy, 2012). The "non-watchstander" group included sailors performing maintenance, sailors involved in food preparation, and sailors who worked normal daytime hours or had a light work schedule.

Initially, all variables underwent descriptive statistical analysis. Next, we averaged the duration of the M-S intervals by participant. General linear model analysis was used to assess the predictor factors of the mean M-S interval duration. Potential predictor factors included ship, sex, rank group, sailor occupational group (watchstander, non-watchstander), watch standing schedule type (fixed or rotating) nested within the sailor occupational group, and number of sections in the schedule nested within the sailor occupational group.

Table 1. Sample demographic and occupational characteristics.

Age, years (median (IQR))	27 (8.25)
Males, # (%)	182 (77.8%)
Rank	
Officers	47 (20.1%)
Enlisted personnel	187 (79.9%)
Departments	
Operations	47 (20.1%)
Engineering	41 (17.5%)
Combat Systems	38 (16.2%)
Executive/Admin	27 (11.5%)
Plans and Tactics	26 (11.1%)
Weapons	23 (9.83%)
Supply	22 (9.40%)
Air	10 (4.27%)
Sailor occupational group, # (%)	
Non-watchstanders	71 (30.3%)
Watchstanders	163 (69.7%)
Fixed	110 (47.0%)
Rotating	53 (22.7%)
Watchstanders by watchbill, # (%)	
3 h-on/9 h-off	72 (30.8%)
5 h-on/15 h-off	47 (20.1%)
6 h-on/18 h-off	10 (4.27%)
6 h-on/6 h-off	10 (4.27%)
4 h-on/8 h-off	8 (3.42%)
5 h-on/10 h-off	4 (1.71%)
Other schedules	13 (5.56%)
Watchstanders in watchbills by number of sections (i.e., sailors per duty position), # (%)	
Two-section watchbills	10 (4.27%)
Three-section watchbills	19 (8.12%)
Four-section watchbills	134 (57.3%)

IQR: interquartile range.

Statistical analysis was conducted with JMP Pro 15 statistical software (SAS Institute; Cary, NC). Data normality was assessed with the Shapiro-Wilk W test. An alpha level of 0.05 was used to determine statistical significance. Summary data are reported as mean $\pm$ standard deviation or median (interquartile range (IQR)) as appropriate. The Tukey's Honest Significant Difference (HSD) test was used for *post hoc* pairwise comparisons.

Results

The median age of participants was 27 years and most were male (Table 1). Participants slept on average 6.55 $\pm$ 1.00 h/day with $\sim$69% sleeping 7 h or less. On a daily basis, $\sim$80.7% of the participants split their sleep into 1.5 episodes (median value with IQR = 0.63). Split sleep was more pronounced in watchstanders (Fisher's Exact Test, $p < 0.001$; Relative Risk (RR) = 1.48 (95% Confidence Interval (CI) = 1.21–1.81)).

The most frequently reported meal was dinner (62.2%) followed by lunch (23.2%), breakfast (10.7%), and midrats (3.85%). The overall median duration of M-S intervals was 4.50 h (IQR = 4.75). Approximately 10% of the M-S intervals were $\leq$ 15 min in duration (25% were $\leq$ 2 h and 35% were $\leq$ 3 h in duration). The median M-S interval after midrats and breakfast was 1 h (IQR = 3.5–3.88). In contrast, the median M-S interval after lunch was 6.5 h (IQR = 8.5) and 4.8 h (IQR = 3.5) after dinner.

Figure 1 shows the duration of the M-S intervals versus the start time of the sleep episode following the meal. A diagonal pattern is associated with the fixed meal periods in the ship's schedule and sailors skipping meals. For example, most sailors who went to sleep around noon had lunch (their M-S interval is $\sim$1 h). Some sailors, however, had breakfast but skipped lunch (their M-S interval is $\sim$5 h).

Next, we aggregated M-S intervals by participant. Approximately 18% of the participants had an average M-S interval of 3 h or less. Adjusted for confounding factors (ship, sex, rank), results of the general linear model analysis (overall model: $F(12,221) = 4.66$, $p < 0.001$; $R^2 = 0.20$) showed that watchstanding ($p < 0.001$) and the number of sections in the watchstanding schedule ($p < 0.001$) were associated with the length of the M-S interval. The type of watch schedule (fixed or rotating) was not a statistically significant predictor ($p = 0.672$). Detailed results are shown in Table 2.

Post hoc analysis showed that sailors on the two-section watchbill (all were from the Operations Department working on the 6 h-on/6 h-off) had the shortest M-S intervals (adjusted M = 0.934 hours, SE = 0.724) compared with M-S intervals of sailors on 3-section watchbills (adjusted M = 4.10 hours, SE = 0.522; HSD test, $t = 3.86$, $p < 0.001$) and on four-section watchbills (adjusted M = 3.97 hours, SE = 0.287; HSD test, $t = 4.39$, $p < 0.001$). No statistically significant differences were identified between 3- and 4-section watchbills. Lastly, non-watchstanders had the longest M-S intervals (adjusted M = 4.85 hours, SE = 0.313) compared with watchstanders (HSD test, all $p < 0.050$).

Discussion

The first important finding from our study is that 18% of participants eat a meal 3 h or less (on average) before their bedtime. These sailors have an increased risk of developing GERD (Fujiwara et al., 2005). On average, watchstanders have shorter M-S intervals compared with non-watchstanders. This trend is especially evident in the two-section, 6 h-on/6 h-off system, which had the shortest M-S intervals ($\sim$55 min). Of note, two section watchbills are characterized by split sleep, worse sleep quality, elevated daytime sleepiness, and more severe insomnia symptoms compared with watchbills with more than two sections (Shattuck and Matsangas, 2019).

Also, we identified 19 instances in which sailors reported eating before the night shift, staying awake through the night, and sleeping later. Meal inertia, i.e., night eating and staying awake, working through the night (Gupta et al., 2018), affects vigilance performance by decreasing response speed and increasing the number of attentional lapses. More

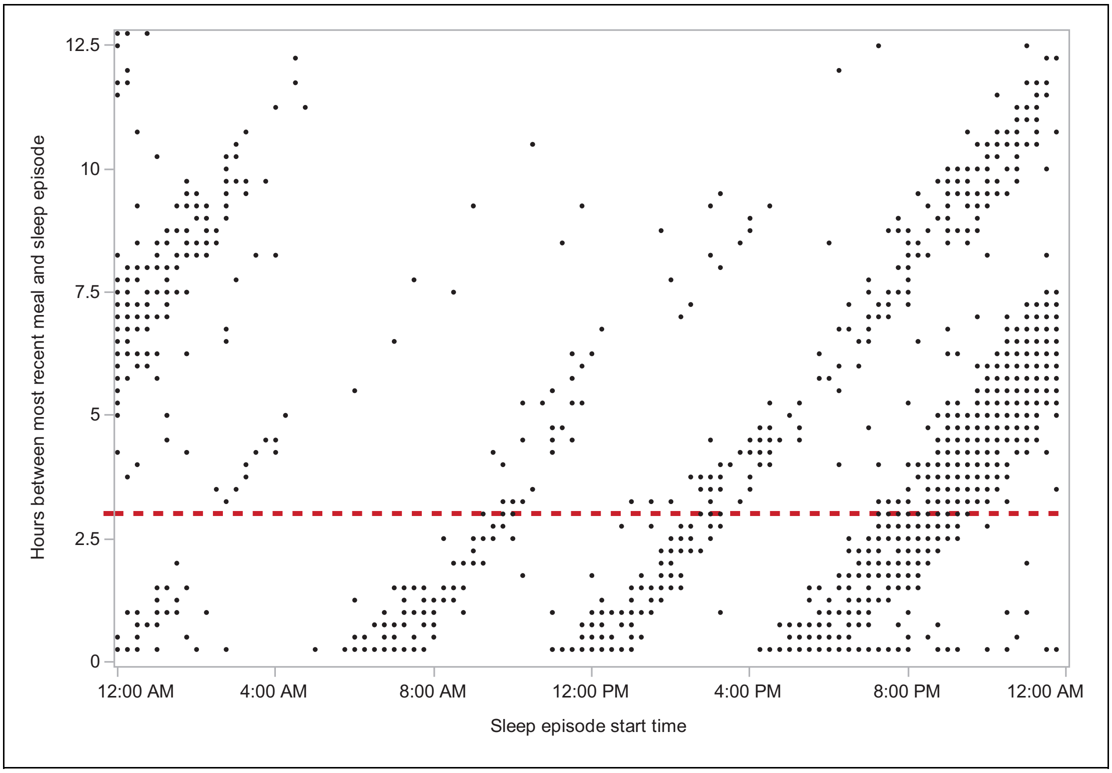

Figure 1. Hours between most recent meal and subsequent sleep episode. Grey areas denote meal times. The dotted horizontal line shows the criterion of the 3-h M-S interval.
M-S: meal-to-sleep.

Table 2. Predictors of the length of the M-S intervals.

Factor	Coefficient	95% CI	Partial η^2	p value
Ship	-	-	0.060	0.003
"A"	0.504	0.035 – 0.971	-	0.035
"B"	0.713	0.148 – 1.28	-	0.014
"C"	−0.910	−1.65 – −0.170	-	0.016
Sex (Female)	−0.146	-0.462 – 0.170	0.004	0.364
Rank	-	-	0.039	0.066
E-1 to E-3	0.325	−0.401 – 1.06	-	0.378
E-4 to E-6	0.623	0.150 – 1.10	-	0.010
E-7 to E-9	0.426	−0.308 – 1.16	-	0.254
O-1 to O-3	0.079	−0.571 – 0.728	-	0.811
Being a non-watchstander	0.923	0.549 – 1.30	0.097	<0.001
Fixed watch schedule[a]	−0.090	−0.507 – 0.328	0.001	0.672
Number of sections in the watch schedule[a]	–	–	0.082	<0.001
Two-section	−2.07	−3.01 – −1.13	-	<0.001
Three-section	1.10	0.322 – 1.87	-	0.006

Note: Box Cox Y transformation applied to M-S intervals
[a]Nested within sailor occupational group (watchstander, non-watchstander)
CI: confidence interval; M-S: meal-to-sleep.

importantly, though, the deterioration in performance lasts throughout the night. Even though the prevalence of eating before night shifts was low in our sample, the potential implications for personnel and ship safety are important, and should be investigated further. Lastly, our findings suggest that a number of sailors skip meals altogether. Based on our observations during the underway data collection periods and sailor comments, we postulate that skipping meals can be attributed to sailor watch schedules and work duties, as well as sailors choosing to sleep instead of eating.

Our findings may be important for seafarers and for sailors in the naval operational environment. The work environment of the seafarers, however, is in general organized on a three-section system (ILO, 2006). Therefore, the problem of short M-S intervals may not be as pronounced in merchant shipping as in the naval forces. In contrast, the two-section watch standing schedules are more common on Navy ships, but our review failed to identify any studies that focused on the length of M-S intervals.

Our study has a number of limitations. First, sailors were asked to report meals on their logs without other information (meal size, food choice, etc.) due to operational constraints. Second, we did not explicitly ask sailors to report eating snacks, stored food, etc. Also, dietary behaviors and nutritional patterns are affected by multiple factors to include the individual's knowledge, socioeconomic status, eating habits, food availability, availability of time to eat, and convenience (Zorbas et al., 2018). Future efforts should explore the association of the above factors with sailor dietary behaviors when at sea, but also incorporate additional quantitative and qualitative methods to collect appropriate information, e.g., video in mess decks to assess, documenting eating habits in a food log or app, use of vending machines on the ship, focus groups with sailors. Lastly, the number of sailors included in our analysis was approximately 15% of the sailors onboard, due to incomplete/missing logs. Despite being small, the study sample was representative of the crew in terms of demographic and occupational characteristics.

Conclusion

Watchstanders, and especially those working on two-section watchbills, tend to have their meals close to their bedtime. Given the busy and rigid schedule sailors have when underway, we postulate that the above meal-versus-sleep behavior is attributed mainly to the ship's meal schedule in relation to sailor's watchbill, and less so to sailor's choice. To provide appropriate recommendations regarding healthy dietary patterns, we will continue assessing dietary behaviors and food choices while underway, especially as they relate to sailor work hours, circadian rhythms, and sleep practices (McHill et al., 2017).

Future efforts will focus on documenting sailor food choices while underway, and changes of food choices and body mass index during deployments. Our goal is to provide appropriate recommendations to the USN leadership regarding nutrition interventions to protect sailors against the consequences of poor dietary patterns/behaviors in association with their watch/work schedules.

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Authors' contributions

Conception: NLS. Analysis: PM. Both authors interpreted data, edited the manuscript, and approved the final draft.

Availability of data and materials

The study data can be made available on request to the corresponding author.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Consent for publication and ethical approval

Study procedures were approved by the Institutional Review Board of the Naval Postgraduate School. Participants provided written informed consent.

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